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DEVELOPMENTS IN SOYBEAN RESEARCH AT THE NORTHERN REGIONAL RESEARCH LABORATORY[1,2]

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The object of our commodity project on soybeans and other oilseeds is to develop new scientific, chemical, and technical uses, and new extended markets and outlets for oilseeds and their constituents. Naturally, during the past several years our work on this project has been limited primarily, but by no means exclusively, to the most important oilseed crop of this region. Because soybeans are a comparatively new crop, the need for and the possibilities of achievement in research on the utilization of the soybean and its constituents is greater than for any other oilseed commodity.

Our research at this Laboratory is divided among seven divisions, all but two of these divisions having direct interest in soybeans. The five divisions that have been or are actively engaged in research on some phase of soybean technology are Fermentation Division, Engineering and Development Division, Commodity Development Division, Analytical and Physical Chemical Division, and Oil and Protein Division. For instance, the Analytical and Physical Chemical Division, as the name suggests, is concerned with analysis for oil content, fatty acid composition, and other problems related to analytical and physical characteristics. The Engineering and Development Division is concerned with pilot-plant studies on unit operations involving soybean processing. The Oil and Protein Division is primarily and almost exclusively concerned with soybeans. Since oilseeds are composed mainly of oil and protein, it is easy to understand why this last named Division has its greatest interest in oilseed commodities. With soybeans the most important oilseed crop of this region, the direction of most of our attention to soybeans is understandable.

Here at the Northern Laboratory we are equipped primarily to deal with the fundamental aspects of problems associated with the industrial utilization of soybeans, as contrasted with their utilization in foods or feeds. However, we have been doing considerable work on edible oil and on foods for humans from soybeans and soybean meal. This work will be expanded during the next several years under the Research and Marketing Act with the aim of solving many of the problems facing these outlets for soybeans and soybean products. With both the food and industrial nonfood uses we are prepared on occasion to work on specific practical problems, such as the development of new formulas for adhesives or paints. Usually these formulating problems are limited in scope and duration. But some of them

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2/ One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

continue for long periods as, for example, paints from soybean oil. By the study of the fundamental aspects of practical problems and by studies in formulation, we have succeeded in making a number of worth while contributions to soybean technology.

When this Bureau first started its research on soybeans, at the U. S. Regional Soybean Industrial Products Laboratory, Urbana, Illinois, a policy of publicizing its information was established. Since then more than 170 papers or scientific reports have been published to increase the knowledge of soybean chemistry and technology. It is impossible because of the shortage of time to attempt a review of all these papers that deal with our developments. However, I do wish to list some of the more important of our specific contributions.

Our important contributions are:

1. Studies on the utilization of nonbreak and alkali-refined soybean oil for paints and varnishes.

2. Precise determination of oil content and lack of change in oil content under conditions of commercial storage.

3. Liquid-liquid fractionation of soybean oil with furfural to give paint and edible oil fractions.

4. A process for alcoholic extraction of soybeans.

5. Utilization of soybeans for food use.

6. Studies on the flavor stability of soybean oil including methods for evaluation and the use of citric acid as a metallic inhibitor.

7. Protein adhesive for shotgun shell casings.

8. Plywood adhesives for hard and soft woods.

9. Polyamide resins from soybean oil.

10. Studies on the composition of soybean lecithin.

Other developments worth mentioning are a standardized factory-scale process for Chinese soya sauce, use of soybean meal in plastics, the analysis of oil for fatty acids, studies on conjugated oils, and so on. However, I want to tell you about four of our developments.

<u>Protein Adhesive for Shotgun Shell Casings</u>

In the search for an adhesive derived from agricultural products, an ammunition manufacturer sought the help of the Northern Laboratory on the possibility of using soybean protein as an adhesive in shotgun shell casings. Because of their background of experience on the behavior of soybean protein,

Dr. Smith, Mr. Babcock, and Mr. McKinney of this Laboratory were able to develop readily on a laboratory scale several formulations of soybean protein adhesives which showed definite promise.

In cooperation with these chemists, the industrial company first conducted pilot-plant runs and then full-scale plant trials to evaluate these formulations, and a large number of experimental shells were made for testing. The casings are made by rolling a special sheet of paper on a mandrel. While this operation proceeds, a thin solution of the soybean adhesive is spread over the surface of the paper. The cylindrical, laminated casings are discharged from the machine at the rate of 50 to 60 per minute. Shooting trials and aging tests were conducted to determine if the casings made with soybean protein deteriorated during storage. The shells were found to be equal or superior to those that the company had manufactured previously. In particular, the shell casings were "tougher" or more "leathery" and had better "water resistance," both characteristics being improvements in the right direction. Actual commercial use by this company of soybean protein for shotgun shell casings was started 1 year ago.

This research was strictly a study of formulations. It was not fundamental. It was, however, an opportunity to make a direct contribution to utilization on a specific problem and we made it. The entire work required no more than the time of one man for a 3-month period.

Plywood Adhesives

This country annually produces large quantities of soybean oil meal which are marketed almost entirely as feed for livestock and poultry. For example, 3 million tons or more of soybean oil meal was produced in 1947. Only a very small amount of this was used industrially.

One of the industrial uses for soybean oil meal is the preparation of adhesives which are widely used in soft and hard plywood industries. Plywood bonded with soybean adhesives is considered to be water-resistant but not waterproof.

During World War II, the plywood industry was required to produce large quantities of waterproof plywood for the aircraft industry. For this purpose the phenolic resins rather than soybean adhesives were used. In 1942-44, this use of phenolic resins increased from 21 to 29 million pounds, while the use of soybean adhesives was decreasing from 45 to 37 million pounds.

A method was sought to reduce the unfavorable trend of soybean adhesives and to economize on the use of phenolic resins, which were critical materials. A. K. Smith and G. E. Babcock of this Laboratory discovered that substantial amounts of the soybean meal which is a byproduct in the manufacture of soybean protein could be used as an adhesive with the phenolic resins.

Although a portion of this work concerned formulation, a very considerable portion involved studies on the preparation of phenolic resins from phenol and formaldehyde, and from resorcinol and formaldehyde, and on the compatibility of these resins with leached soybean meal and destarched corn gluten. It was actually a more fundamental problem than the first problem mentioned. It indicates, therefore, both a fundamental and a practical approach to a specific problem which resulted in commercial utilization.

One company actually made use of this discovery and produced a plywood suitable for aircraft construction. It used a half million pounds of soybean meal in its waterproof plywood during a 12-month period from 1944 to 1945. This development served to extend supplies of phenolic resins for adhesives during the last phases of the war.

Polyamide Resins

Early in the work on industrial oils at this Laboratory, it was decided to study the reactions of linoleic acid, the major fatty acid component of soybean oil, and to study the possibilities of producing new polymeric products from it. This objective led to methods of producing dimeric and trimeric linoleic acids, i.e., two and three molecules of linoleic acid combined. These acids served as a basic chemical for preparing a wide variety of new materials. These dimeric and trimeric fat acids can be prepared directly from soybean oil, the process producing a mixture which we call polymeric fat acids. These acids, like phthalic anhydride used in the manufacture of alkyd resins, can be reacted with glycols, alcohol amines, and diamines to give a variety of polymeric resinous and rubbery materials. One of these materials was used for 6 to 8 months during the war as a rubber substitute. It was prepared with ethylene glycol, a permanent anti-freeze, and a number of conventional rubber compounding materials in unconventional amounts. You may have heard of this material under the name of Norepol or Agripol. Fundamental studies actually led to the preparation of synthetic rubber from soybean oil, but no production of this material was achieved.

However, continued search for new materials led to the work on the ethylene diamine polyamide for heat sealing of food packages. This product, called Norelac, proved so interesting that two commercial concerns produced it during 1944-46 on a semi-commercial scale and General Mills, Inc., is now operating a plant with a capacity of 100,000 pounds per month.

This work represents a fundamental approach to a general problem which resulted in commercial utilization of soybean oil for a new industrial product.

Soybean Lecithin

The last development that I want to mention is fairly new; indeed, we have published no papers on it. It is of direct interest to your group. During the past year we have found methods of effectively separating the components of soybean "lecithin." The methods are applicable only to laboratory work but could apply to commercial operations if cost was no

object. We have been able to separate soybean "lecithin" into five different components. Four of these components are phosphatides and the approximate percentages present in soybean "lecithin" are 29 percent lecithin, 31 percent cephalin, and 40 percent inositol-phosphatides. There are at least two different inositol-phosphatides.

This composition for soybean "lecithin" may be somewhat of a surprise to you because most books on soybeans report 30 to 35 percent lecithin and 65 to 70 percent cephalin. Currently we are engaged in attempting to determine the materials present in the inositol fractions. Where our work will lead or whether it has practical application, we do not know as yet. However, we feel sure that a better understanding of the composition of this material will prove helpful in the next several years when lecithin probably will be much more available and lower in price than heretofore. This research may lead to new methods of chemical treatment and modification of value to the industry. The lecithin problem is actually an industry-wide problem and one on which we intend to do more work in the immediate future.

To summarize, the Northern Laboratory has been vitally interested in and actively working on many problems related to soybean technology. You can expect this Laboratory to discover new information on soybeans and also to bring out new developments for industrial consideration during the next several years.